



Citrus for Hawai'i's Yards and Gardens

Citrus trees are among the favorite fruit trees grown around Hawai'i's homes. They are relatively small and widely adapted. The main types grown are lemon, lime, orange, mandarin (tangerine), tangelo, grapefruit, and pummelo. Some culinary and ornamental citrus species are also grown.

Citruses of various kinds can be grown in Hawai'i from near sea level to 2000 feet elevation and above. Most grow best in sunny locations where temperatures range between 65° and 90°F. Citruses in general are better adapted to dry than to wet climates, and earlier publications recommended leeward rather than windward areas for citrus production.

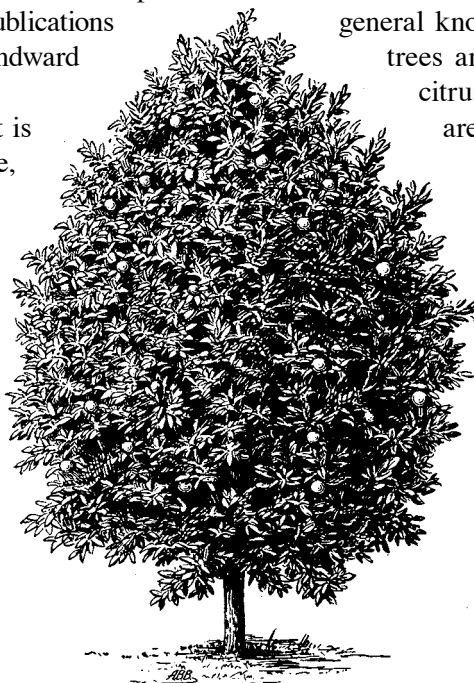
The citruses in which sweet fruit is desirable (such as orange, tangerine, tangelo, grapefruit, and pummelo) are generally best grown at lower elevations, from sea level to 500 ft. When they are grown in or above the 500–1000-ft elevation range, where cooler temperatures are common, the fruit may fail to develop high levels of sugar and instead remain acid, which results in sourness. At 500–1000 ft, navel orange and tangerine produce fruit of adequate quality. Higher elevations (above 1000 ft) are generally best suited to growing lemons and limes.

Fruit of citruses such as orange and tangerine usually fails to develop color when grown at Hawai'i's lower elevations, and a green or green-yellow skin coloration is normal in ripe fruit. In areas with cooler nights, the fruits turn bright orange upon ripening.

Climatic conditions vary widely in Hawai'i from place to place over fairly short distances. This variation and the wide variation in the genetic diversity of citrus means that confident statements about which types or varieties

grow best in a particular location are difficult to make.

Although citrus has been a crop of minor significance at various times since its post-Cook importation to Hawai'i, there has not been much experimentation on citrus horticulture at the University of Hawai'i. Only a few studies on variety suitability or crop management under Hawai'i conditions have been reported. The recommendation of varieties in this publication incorporates the practical experience of CTAHR horticulturists. The advice on cultural practices given here draws on the general knowledge of practices suitable for fruit trees and incorporates recommendations on citrus production from other citrus-growing areas.



Citrus types and varieties

Citrus originated in subtropical South and Southeast Asia, and its diversity of types probably was developed largely in China and India. Representatives of citrus gradually spread westward, reaching Spain by the late Middle Ages, and were taken to the New World by Columbus and other explorers.

The citrus group crossbreeds freely, which is why its members so rarely produce true to type from seed. About a dozen primary spe-

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cies of the genus *Citrus* are recognized, but the group's genetic scope, represented by its many species and possible hybrids, is of vast complexity and offers great promise for development of improved varieties.

While a very few citrus varieties ("nucellar" types, such as the rootstock 'Heen Naran') produce true to type when grown from seed, most do not. The citrus trees available from nurseries and garden centers are clonally propagated by grafting a piece of the desired "scion" variety onto a seedling rootstock. Often the rootstock variety has been selected for its influence on producing high-quality fruit or its tolerance of certain citrus diseases. Some rootstocks are claimed to have a "dwarfing" effect, resulting in smaller tree size.

Navel orange is probably the most popular citrus grown in home gardens in Hawai'i. The fruit is relatively easy to peel, contains few or no seeds, is juicy and sweet, and provides a nutritious snack. 'Washington' navel, which ripens from October to January, is widely grown throughout the state. 'Pera', 'Raratonga Seedless', 'Rico No. 2' (a nucellar type), and 'Tabata Navel' are recommended for Hawai'i. 'Valencia', 'Shuekhan', and 'Texas Joppa' are other varieties that are grown here.

Mandarin is also common in home gardens. The fruit is flavorful and easy to peel. 'Fairchild', 'Fremont', 'Lee', and 'Nova' are recommended for Hawai'i. 'Okinawan', 'Honey', 'King', and 'Dancy' are also grown.

Grapefruit produces tart, juicy fruits. Grapefruit varieties that grow well here include 'Marsh Seedless', 'Puma' (a grapefruit-pummelo cross), 'Ruby Red' (also called 'Glenred' or 'Ruby'), and 'Star Ruby.' Pummelo (also called zabon or jabon) is a close relative of the grapefruit, but its fruit is less tart. Pummelo trees require slightly more growing space because of their large fruit. Favored varieties produce excellent quality fruit with flesh that is sweet and firm, which makes it easier to eat with the fingers. 'Chandler', 'Haiku B', 'Kao Pan', 'Leslie', and 'Scudder' are recommended for Hawai'i. 'Diamond Head', 'Pauthel', 'Sakata', 'Tahitian', and 'Thong Dee' are also grown.

Tangelo, a cross between mandarin and grapefruit, is liked for its ease of peeling and abundant juice. 'Minneola' and 'Orlando' grow well here. Recommended varieties of tangor, a mandarin-orange cross known for its sweetness, are 'Murcott' and 'Ortanique.'

Citrus types grown for juice for flavoring include 'Meyer' lemon, 'Bearss' lime (a.k.a. 'Persian' or 'Tahitian' lime), and 'Key Lime' (a.k.a. 'Mexican' or 'Chinese' lime); these

may produce fruit throughout the year. 'Kaffir' lime leaves are used as a flavoring in Thai cooking.

Some citrus are grown for ornamental purposes. Calamondin is often planted as a bonsai or container plant. Its juice is used as a condiment in Philippine cooking. Kumquat, in a genus related to citrus, can be eaten with its rind or used in marmalades and is also used as an ornamental. Adapted kumquat varieties for Hawai'i include 'Nagami', 'Meiwa', and 'Marumi'.

The availability of citrus varieties in Hawai'i's garden shops and plant nurseries is unpredictable, and not all of those mentioned here are always readily available. Nurseries often bring in varieties that are favored elsewhere, and these introductions may well be worth a try under Hawai'i conditions.

Location and climate

Citrus trees should be planted in an area that receives full sunlight and is protected from strong winds. The soil must have good drainage, and the site should not have standing water during rainy periods. The planting spot should be 15–20 feet away from other trees or structures; this spacing can be closer, depending on the citrus type and how large it becomes. For a general guide to choosing a site and transplanting trees, see CTAHR publication L-4, *Planting a Tree*.

A fruit tree is a long-term investment of your land and effort, and having the soil analyzed is a relatively inexpensive way to help ensure success. A soil analysis is particularly recommended for new planting sites. A "standard" soil analysis, which measures soil pH and available soil phosphorus, potassium, calcium, and magnesium, can be done by the CTAHR Agricultural Diagnostic Service Center or a commercial laboratory (preferably one having experience with Hawai'i's soils).

For information on sampling the soil and arranging for its analysis by CTAHR-ADSC, see the CTAHR publication *Testing Your Soil—Why and How to Take a Soil-Test Sample*, available at www.ctahr.hawaii.edu/freepubs under "Soil and Crop Management," or from UH-CTAHR Cooperative Extension Service offices statewide.

Soil preparation

People often plant fruit trees with a minimum of soil preparation, and sometimes trees so planted grow well without much further care. The following advice is given assuming that the reader wishes to understand the various ways in which soil can be improved for growth of a citrus tree.

If the soil analysis indicates that soil amendments should be added, this is best done before planting. When planting a tree, you need to consider amending not only the soil in or near the planting hole but also the soil in which the tree's roots will be feeding 2 or 5 or 10 years later. This could be an area within an 8–10-foot radius from the planting spot. If the tree has already been planted, the soil around it can still be amended, but to avoid damaging the tree this should be done just beyond the limit of the developing root system, so that the roots can grow outward into the amended soil.

Plant productivity can usually be increased by amending the soil with organic matter, such as compost or well rotted (composted) livestock manure. (See the CTAHR publications *Backyard Composting—Recycling a Natural Product* and *Composted Animal Manures—Precautions and Processing*). If compost is available, apply it in a layer up to 4 inches thick spread over the soil in a circle up to 4–6 feet from the planting spot, as the supply allows, and incorporate it into the top 6–8 inches of the soil.

The soil's acidity or alkalinity, expressed in a soil analysis as soil pH, determines which types of plants will grow well in it. Citrus grows best in a soil with pH 6–7. Soil with a pH below 5.5 requires incorporation of agricultural lime to increase the pH to a level more favorable for plant growth. In highly weathered soils, such as are found in most upland (non-coastal) areas of the Hawaiian Islands, low pH often results in high concentrations of aluminum (and sometimes manganese) in the soil solution that are toxic to root development. Increasing the soil pH to above 5.5 by liming precipitates soluble aluminum and creates a more favorable soil environment for root growth. To be effective in improving soil pH for growth, the lime must be mixed thoroughly into at least the top 6–8 inches of the soil before planting. The application of lime has the added benefit of increasing the soil calcium supply. Agricultural lime and its cousin dolomite, which provides both calcium and magnesium but does not influence soil pH as rapidly as lime, are natural materials considered suitable for “organic” agriculture.

A low level of available soil phosphorus (P) limits plant growth in some of Hawai'i's soils. If a soil analysis indicates P is low, follow the recommendation for amending the soil. P is present in fertilizers as phosphate (P_2O_5). P is most effective when thoroughly mixed into the rooting zone. It is not very available to the plant when it is only spread on the soil surface.

Natural sources of P usable in “organic” agriculture

that have fairly rapid availability include wood ashes and chicken manure, from which P is fairly rapidly available after mixing with the soil, but these materials are low in P content. A natural P source with a higher P content is cooked bone meal, although its P is only moderately available in the short term, compared to rapid-release man-made fertilizers such as triple superphosphate. At the soil pH suggested for citrus, the natural P source rock phosphate is not very soluble and thus is not as effective as it is in acidic soils.

If a soil P deficiency in the rooting zone is not corrected before planting, P fertilizer can be applied later by inserting it into holes under the tree's advancing leaf canopy drip line, where the new roots are growing. Because of the need for extensive contact with the soil to promote solubility, natural P sources are not readily available when applied in holes, whereas soluble P fertilizers placed in these “pockets” can be more readily exploited by roots and delivered to the plant.

In almost any soil environment in Hawai'i it can be assumed that soil nitrogen (N) is limited, and adding it will have a favorable impact on plant growth and yield. Adding compost or manure to provide N is appropriate for “organic” agriculture, although the N content of these materials is often low. Compared to N from natural sources, N from synthetic fertilizers generally has more rapid availability. Whether applied as a rapidly soluble fertilizer or a strong organic source such as chicken manure, excessive amounts of N can damage plant roots.

Both fertilizer N and K (potassium, present in fertilizers as potash, K_2O) move easily into the soil with the wetting front of water and can be applied to the soil surface during later stages of crop growth.

Planting the tree

When planting the potted tree, dig a hole 2 feet in diameter and as deep as the depth of the soil in the pot in which the plant has been grown. If the soil in the planting area has not been amended with organic matter and phosphate as described above, amend the backfill soil with some compost and $\frac{1}{2}$ cup of a fertilizer high in phosphorus, such as superphosphate, treble superphosphate, or a 10-30-10 formulation, to provide initial root stimulation. Remove the tree from the pot and set it in the planting hole. If the plant has become “pot-bound,” gently uncoil the roots and spread them outward over the floor of the planting hole. After backfilling the planting hole, the crown of the tree, which was at the surface of

the soil in the pot, should be level with or slightly above the level of the soil surface around the planting hole. If the plant's crown is below the soil level, a depression will be formed in which water can collect, which can be harmful to the plant.

Firm the backfilled soil around the plant and water it. Subsequently, do not irrigate excessively, but let the soil dry a bit between waterings. In general, water twice a week during the first month after transplanting, and water once a week thereafter. Water deeply (a single deep watering is better than several shallow ones) but not so much as to cause puddling. In windy areas, protect or support the plant (see CTAHR publication L-7, *Staking and Guying Newly Planted Trees*). It is advisable to keep the area around the newly planted tree free of turfgrass and weeds for several feet away from the trunk.

Fertilizer strategies

Where shrubs or trees, including citrus, are being grown in a houselot landscape, turf fertilizer applied to the surrounding lawn areas may be a sufficient source of nutrients—N in particular, since fertilizers for turf are high in N. For homeowners who want to expend some special effort to ensure good growth and yield of the fruit-bearing plants in their landscape, the following information is provided.

Choosing the right kind and amount of fertilizer to apply to citrus trees growing in a given soil and climate environment is an ability that the gardener acquires over time by experimenting and observing. It is difficult to give one recommendation for all situations. The factors that need to be considered are outlined here, and then a generalized recommendation is given.

The age and size of the tree

Young, developing trees need a steady supply of nutrients from frequent, small fertilizer applications. Older, bearing trees need fertilizer in doses timed to meet the demands of their various growth and fruiting stages during the year. The larger the tree, and the more heavily it bears, the more fertilizer it needs.

The strength and type of fertilizer

An effective fertilizer program is based on the amount of nutrients being applied, not the amount of fertilizer. A 16-16-16 formulation contains twice the amount of nutrients as an 8-8-8 formulation (these numbers refer to the percentages of nitrogen, phosphate, and potash, N,

P₂O₅, and K₂O, in the fertilizer). Fertilizer P is needed to promote root growth during tree establishment; in bearing trees, P it is utilized during flowering. N is needed particularly during flushes of new leaf growth. During fruit filling, emphasis should be on providing adequate N and, especially, K.

Fertilizer programs for “organic” production rely on nutrient sources that generally are lower in nutrient content and more gradually available than the synthetic formulations that our recommendations are based on, so relatively more of these natural fertilizers need to be applied. There is not much information available on using fertilizer materials acceptable for “organic” production as the sole source of nutrients for perennial crops in Hawai'i.

The growing conditions, including the soil at the site

Trees that are growing rapidly (during warm, sunny periods, for example) need more nutrients than they do during slow-growth periods. If the soil has nutrient deficiencies, the fertilizer program should be calculated to make up for them. Trees on sandy, coarse, or rapidly drained soils may require more nutrients, or more frequent fertilizer applications, than trees on clay soils, which retain nutrients better.

Citrus grown in coastal regions on soils derived from coral, which generally tend toward being alkaline in pH (>7), will often show interveinal leaf yellowing (chlorosis) suggesting nutrient deficiencies, and the new leaves may also be pale green or yellow, indicating iron deficiency. In these soils such symptoms may be either constant or periodic, and the trees may bear adequately despite them. Applying too much P in routine fertilizer applications can induce iron and zinc deficiencies in plants on these soils; analysis of the soil in the rooting zone can indicate if P is in excess, and fertilizer formulations can be chosen to reduce or eliminate application of P. Choosing fertilizers that supply micronutrients can also help alleviate deficiencies. Adding compost or applying acidulating fertilizers, such as when N is supplied as ammonium sulfate, can help to counteract the natural alkalinity of these soils and improve them for growing plants that are not well adapted to the soil conditions.

Trees that are heavily infested with insects or suffering from disease should not be fertilized until the problem is overcome.

Fertilizer types

Commonly available rapid-release fertilizer formulations

are 16-16-16 (“triple-16”) and 10-20-20. Sometimes these formulations are “plus minor elements”—with added micronutrients. Controlled-release formulations that are fairly commonly available are 13-13-13 and 14-14-14 with 3-month (or 100-day) release patterns; these may also be formulated with micronutrients. In terms of providing the major nutrients during bearing stage, any of these four formulations will do the job adequately, and the following recommendations assume that one of these types is used.

Some specialty formulations are marketed for citrus, or for “avocado and citrus,” with nutrient contents such as 13-6-13 or 10-4-10. These fertilizers with relatively low levels of P make some sense for continuous application under citrus trees, because they may avert the problems encountered with excessive P build-up. These specialty fertilizers are sold boxed in small quantities, imported from the U.S. mainland, and therefore tend to be expensive.

For the fruit-development stage in a heavy-yielding tree, a high-K formulation is desirable. A 10-5-29 fertilizer is formulated in Hawai'i particularly for fruiting trees (it is sometimes called “banana fertilizer”), and some garden shops repackage the large bags designed for purchase by commercial growers into smaller bags more suited for purchase by homeowners.

Generalized fertilizer recommendations

The following recommendations are given in detail for the purpose of informing the reader about how a commercial citrus grower might approach fertilizing trees for maximum growth and production in an orchard. As mentioned earlier, in a houselot, citrus may grow adequately given just the fertilizer applied to the surrounding lawn area. To maximize production, however, a more deliberate approach will help to supply the tree with the nutrients it needs at the time they are needed.

Developing trees

For the first few years of growth, beginning when the tree puts out new growth after planting, if you use a rapid-release fertilizer, it should be applied frequently so the developing tree has adequate nutrition at all times. As the tree grows, the amount applied should increase and the frequency of application should decrease. For example, apply fertilizer every 2 months in the first year, every 2½ months the second year, and every 3 months from the third year on.

An example of a fertilizer program is shown in the table below, which is adapted from recommendations given for Florida conditions. (The Florida program uses 8-8-8, but the table gives comparable amounts of 16-16-16 because triple-8 is not commonly available in Hawai'i.) Use caution when applying triple-16 to the young tree—do not apply too much. A 10-20-20 rapid-release formulation can be substituted using roughly the same amounts as are given for triple-16. The same amounts could also be used with a triple-13 or triple-14 controlled-release formulation, but these should be applied at the release period interval specified on the product label.

Spread the fertilizer over the rooting zone in an area from 6 inches away from the trunk to just beyond the leaf drip line. Irrigate after the application.

Bearing trees

Commercial growers sometimes record the yield of an orchard and gauge fertilizer applications to replace the nutrients taken away in the harvested fruit. For the home garden, less precise fertilizer programs have been developed, based either on the age of the tree or on the size of its trunk (inches of diameter at a height 3–4 feet above the ground). In either case, the annual dose is divided into several applications.

By the fifth year after planting, the tree should be bearing well. The amount for year 5 in the table below is based on a Florida recommendation for commercial citrus production. That program aims to apply 180 pounds of N per acre per year, from the fifth year, to a planting

Example of a fertilizer program for a citrus tree using a 16-16-16 rapid-release formulation.

| Year | Application interval (months) | N lb/yr | Fertilizer lb/yr [†] | Fertilizer applications: number @ lb [†] |
|------|-------------------------------|---------|-------------------------------|---------------------------------------------------|
| 1 | 2 | ¼* | 1½ | 6 @ ¼ |
| 2 | 2½ | ½ | 3 | 5 @ ½ |
| 3 | 3 | ¾ | 5 | 4 @ 1¼ |
| 4 | 3 | 1¾ | 11 | 4 @ 2¾ |
| 5 | 3 | 2½ | 16 | 4 @ 4 |

[†]Amounts calculated for fertilizer per year and per application are approximate due to rounding.

*This targeted nitrogen application, 4 oz per year in the first year, is an estimated amount that may not be right for all situations. The appropriate amount might range between 2½ and 5 ounces, depending on the growth potential offered by the citrus type, the soil fertility, and the growing environment.

with 70 trees per acre. Those trees, planted 25 feet apart, are expected to grow larger and bear more heavily than the average home-garden citrus tree in Hawai'i, so the amount given in the table could be considered a maximum amount for a large, uncrowded, heavily bearing citrus tree in a Hawai'i garden.

In Taiwan, as bearing citrus trees in commercial production increase their yield, application of a 16-8-12 formulation increases over the production years from 7 up to 14 pounds per tree per year. About 40 percent of the dose is applied after harvest to restore tree vigor.

It should be considered that in a houselot, maintaining small tree size may be desirable. For the purpose of keeping the tree from taking up too much space, as well as for keeping fruits within reach for ease of harvesting, it may be best not to maximize growth in the manner that a commercial grower would attempt.

A simpler fertilizer program than given in the preceding table would be to apply fertilizer at 1–1½ pound annually for each year of tree age. Divide this amount into three applications: (1) just before or at flowering, (2) during the stage when fruits are rapidly developing, and (3) 4–6 weeks before fruit maturity. This program would not fertilize so heavily as in the commercial examples as the tree grows older.

Further notes on fertilizers

The easiest way to apply fertilizer is to spread it over the soil surface in a wide band under the leaf canopy drip line. The fertilizer thus broadcast can be lightly incorporated into the surface soil with a hoe or rake, with care taken to avoid damaging feeder roots. Alternatively, the fertilizer can be placed in holes made to the depth of the feeder roots (6–10 inches deep) at random points under the canopy and around the leaf drip line.

Soil phosphorus can increase to an undesirably high level after long-term application of high-phosphate fertilizers, such as 10-30-10. If this is part of the garden's history, a soil analysis should be done to check the phosphorus level. If it is in excess, a zero-P formulation can be created by mixing equal amounts of urea and muriate of potash to produce a formulation that is about 23-0-30. If this is being substituted for 10-20-20 or 16-16-16, about half as much would be applied. The zero-P formulation can be applied until further tests indicate that P is no longer in excess.

Citrus trees may benefit from periodic applications of micronutrients such as iron, zinc, and manganese. In

commercial orchards, leaf tissue analysis is commonly done to identify deficiencies of micronutrient elements. In the home garden, observation of interveinal chlorosis (yellowing of leaves between the veins) is an indication that micronutrients are deficient. In some locations in Hawai'i it appears that occasional interveinal chlorosis is a relatively normal phenomenon in citrus, perhaps related to the season or to applications of NPK fertilizer formulations. If the chlorosis is severe or persistent, the tree likely will benefit from application of micronutrients. Some fertilizers containing micronutrients are formulated to be applied directly to the leaves. There is a trend among fertilizer manufacturers toward including micronutrients in common home garden formulations such as 10-20-20.

Water the tree thoroughly after applying fertilizer to the soil. Citrus trees should never be allowed to show symptoms of water stress, such as drooping leaves. In many areas, one deep irrigation each week that soaks the entire rooting zone is adequate. Frequent, shallow irrigation is not good for citrus trees.

Plant management, pests, and diseases

Harvest

The fruits are harvested when half to two-thirds of the rind turns color. Fruit left on the tree beyond complete coloration may have lower quality. When ready for picking, most citrus fruit will readily detach from the tree by twisting the fruit at an angle to the stem, although with mandarins the stem should be snipped to avoid tearing the fruit skin. Store citrus fruit at room temperature until ripe, then refrigerate. Refrigeration at 35–40°F will prolong the shelf life of the fruit.

Pruning

Prune to remove dead branches and limbs that cross over. Remove suckers ("water sprouts") and any shoots arising from the rootstock. Thin out the interior branches to allow light to enter and air to circulate. This routine pruning can be done at any time of the year, but it is best done just after all the fruit has been harvested. Pruning just before flowering will reduce production. Severe pruning will cause a vigorous vegetative growth response, resulting in decreased yield in the following fruiting period.

Insects

Insects attacking citrus include scale, aphids, whitefly, Chinese rose beetle, citrus swallowtail caterpillar, citrus

blackfly, and citrus leafminer. Beneficial insects (including parasites and predators) help to control certain insect pests, including the citrus swallowtail caterpillar, aphids, whitefly, scale, and blackfly. Pesticides applied to control pest insects will also deplete the numbers of beneficial insects. Insecticidal soaps and oils can be used to control mites and soft-bodied insects such as scales and aphids. Insecticides that contain the bacterium *Bacillus thuringiensis* var. *kurstaki* or *aizawai* help to control caterpillars such as the citrus swallowtail. Fruit flies insert their eggs into fruits, which can cause rot as the larvae develop and feed. Fruit fly control requires a combination of approaches including properly disposing of fallen fruits and using lures and bait-sprays; for more information, see CTAHR publication IP-4, *Managing Fruit Flies on Farms in Hawaii*.

Other pests

Among non-insect pests of citrus, the most noticeable is the broad mite, which causes leaf curling by feeding on new growth flushes. These mites also feed on the fruit rind, resulting in a bronzing or dulling of the skin; this damage is cosmetic, and its control is generally not necessary.

Snails cause occasional leaf damage by chewing holes that resemble the damage from Chinese rose beetles.

Foot rot disease

Foot rot is an occasional disease caused by infection by *Phytophthora*, a soil-borne fungus-like pathogen. Most rootstocks used are tolerant of this disease, but the desirable varieties grafted to the rootstock are not, and problems can occur when the graft union is too close to the ground and soil can splash onto it, or when branches heavy with fruit lay on the ground. Bark damage near the ground by careless weed-whacking can also allow entry of the fungus.

Citrus tristeza virus

Of the diseases affecting citrus, citrus tristeza virus (CTV) is the most serious and widely prevalent. No control is known for this disease, but its effects can be diminished by taking certain precautions in selecting varieties to plant, and in propagating.

CTV manifests as two disease problems in citrus. The first, known as “quick decline,” is rare in Hawai'i because susceptible sour orange, used as a rootstock in Texas and California, where CTV is not present, is not used here, where the problem is avoided by grafting onto disease-tolerant rootstocks such as ‘Heen Naran’ and

‘Cleopatra’, two mandarin cultivars.

The second—and most serious—problem caused by CTV is referred to as “stem pitting,” a condition that is often obvious from deformations along sections of the tree's branches. This is a major problem with grapefruit and ‘Mexican’ lime, often severely affecting their growth and yield. It is a moderate problem in orange, tangelo, and ‘Tahitian’ lime, and a minor problem in mandarin and pummelo. Rootstock selection has no influence in mitigating stem pitting.

There is a range of virulence in CTV strains. Some citrus varieties obtain tolerance of more virulent strains by having become infected with a milder strain. This “cross-protection” occurs naturally here, but in some citrus-growing areas the grafted plants are inoculated with mild strains of CTV in the nursery. Some nurseries in Hawai'i test their citrus plants and are certified CTV-free. Other propagators are not certified but select scion material only from plants in which they have observed some apparent tolerance of CTV.

Citrus blight

Citrus blight is a rapid decline of all or part of a tree, and its cause is unknown. In Hawai'i it is often confused with CTV disease. Citrus blight is not found in California but is a common problem in humid, more tropical areas such as Florida, Central America, and Hawai'i.

Other diseases

Tangelo and lime are highly susceptible to citrus scab infection. Other diseases found on citrus include melanose, algal spot, and sooty mold; these can be controlled by using copper-based fungicide sprays labeled for use on citrus. Sooty mold appears as a black film on the leaves and fruits; it can be eliminated by controlling scales, whiteflies, and aphids. The lichens commonly found growing on the bark of the trunk and branches of citrus trees do not harm the trees and need not be controlled.

Citrus in Hawai'i

Citrus arrived in the Hawaiian Islands before 1800, brought by explorers following the Western “discovery” visit of Captain James Cook. Orange trees, according to D.L. Crawford in *Hawaii's Crop Parade*, were first brought from Tahiti, and the seedlings grown from these plants were known as “Polynesian oranges,” while a later import from the West Indies came to be called the “Kona orange.”

The tasty citrus fruits were received with enthusiasm in the islands and were planted widely, in small plantings, during the first half of the nineteenth century. Between provisioning whalers and other ships and exporting fruit to the gold fields of California, producing oranges was quite lucrative for a while. After the Gold Rush, California began its own citrus industry. In Hawai'i, sugarcane, coffee, and livestock became more profitable, and fifty years after the peak of its citrus export business, Hawai'i had become a net importer of citrus.

The Hawaii Agricultural Experiment Station (HAES) began to revive interest in citrus with a variety planting in Makiki on O'ahu and publication of a bulletin by J.E. Higgins in 1905. The difficulties growers had already noted with various pests and plant diseases, which necessitated costly spray programs, became exponentially more complex with the introduction of the Mediterranean fruit fly to the islands in about 1910. Before this pest came under some degree of biological control resulting from importation of predator insects, it infested citrus so thoroughly that the locally grown fruits fell dramatically out of favor.

By the 1930s, fruit fly biological control efforts allowed development of a small orange industry in Kona. The coffee cherry was a preferred host of the fruit fly for egg-laying, and the predators effectively found these maggots, so fruit fly numbers were kept in check. HAES responded to this window of opportunity in the fight against the fruit fly by issuing another bulletin on citrus by Willis Pope in 1934.

Several years afterward, Crawford gave an astute assessment of the situation regarding a citrus industry in Hawai'i:

"Hawaii does not have ideal conditions for the production of oranges on a commercial scale. The climate is a little more tropical than it ought to be for the ideal situation, and the general conditions of climate and terrain are too favorable to insect pests. Without a winter season to check them the insects keep on multiplying throughout the entire year and become enormously abundant, and the mountainous nature of most of our fruit producing lands makes it extremely difficult and expensive to apply the necessary insecticides. We fall, therefore, into the easier way of relying on parasites to control the pests, but they seldom do as thorough a job as we really need for commercial success.

"Then, too, oranges in our tropical conditions do not take on the uniformity of color that the California oranges do, and this makes them seem less desirable to most consumers who judge a fruit first by its appearance. In flavor, our Hawaiian (Kona) oranges are sweeter than California oranges but they lack the acid tartness which people like and so are usually rated as inferior to the imported product in flavor. This would militate against the development of any large commercial industry in citrus fruits.

"It is possible, however, that it would be well worth while to increase the plantings of orange trees in back yards and home gardens. They grow so easily that any householder with sufficient space could have a few trees for supplying home needs. Even if the fruits so produced were not of the best appearance, they would taste better because they grew at home. Likewise, a lime tree would supply home needs for lemons for a large part of each year, and a mandarin or Kona orange tree or two would save the expense of buying at the market."

CTAHR horticulturists continued to plant and evaluate promising citrus varieties until the early 1990s, when a new grapefruit, 'Puma', was released. Since then, retirements of fruit scientists have brought a halt to efforts with citrus. With the current popularity of Hawai'i-grown fruits in the restaurant sector and among consumers, entrepreneurial growers have tried and probably will continue to attempt to make a go of producing locally grown citrus for the Hawai'i market. And homeowners can still do well to heed Crawford's advice and plant a citrus tree or two in the home landscape.

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